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IRON FORTIFICATION OF DEHYDRATED MASHED POTATOES

INTRODUCTION

DIETARY IRON deficiency has been recognized as a significant nutritional problem in the United States (White House Conference on Food, Nutrition and Health, 1970). One approach to the solution of the problem is the addition of iron to foods consumed by large segments of the population. The feasibility of fortifying whole milk with various iron compounds was reported recently by Edmondson et al. (1971).

The high per capita consumption of potatoes (118 lb in 1970), the increasing acceptance of dehydrated potato products (USDA, 1971) and their inclusion in the U.S. Department of Agriculture Needy Families Program make this food a potentially suitable vehicle for iron fortification. One commercial producer of potato flakes is enriching his product with "iron phosphate," but the level of addition (6.8% of the recommended dietary allowance for a 22-yr-old man in one 4 oz. serving) is probably too low to have much nutritional impact. The desirability of adding higher levels of iron must be reconciled with the possible occurrence of "after-cooking darkening," a discoloration resulting from the formation of iron-chlorogenic acid complexes (Burton, 1966) and with the catalysis of oxidative rancidity during storage (Ingold, 1962).

Exploratory studies were undertaken at Eastern Regional Research Center (ERRC) to determine the technical feasibility of fortifying dehydrated mashed potatoes with nutritionally significant levels of iron. The results of these studies are reported herein.

[1] A center cooperatively operated by the USDA North Central Region, ARS; the Minnesota Agricultural Experiment Station; the North Dakota Agricultural Experiment Station; and the Red River Valley Potato Growers' Association.

EXPERIMENTAL

Iron compounds and levels of fortification

Dehydrated mashed potatoes were fortified with a number of commercially available iron compounds (reagent or U.S.P. grade) as well as with several experimental iron complexes developed at ERRC (Table 1). The latter have been described by Jones et al. (1971, 1972).

Compounds were tested at three levels corresponding to 2, 5 and 10 mg iron per 100g mashed potatoes. The highest level represents approximately 55% of the recommended daily dietary allowance for pregnant and lactating women (NRC, 1968).

Effect of iron compounds on the color of mashed potatoes

Since the induction of after-cooking darkening was believed to be the most serious obstacle to iron fortification of potato products, iron compounds were screened initially on the basis of color formation in mashed potatoes.

Iron compounds were added in aqueous solution or as finely ground powders to 100g portions of fresh mashed potatoes, prepared

Table 1—Discoloration of iron fortified mashed Idaho Russet potatoes

Iron compound added	Iron content (%)	Relative biological value (%)	Mashed potato color, mg Fe/100g: 0	2	5	10
Ferrous sulfate	20.0	100[a]	Normal	Dark	Dark	Dark
Ferrous ammonium sulfate	14.2	99–100[a]	Normal	Dark	Dark	Dark
Ferric ammonium citrate	17.5	98–115[a]	Normal	Dark	Dark	Dark
Ferric chloride	20.6	26–67[a]	Normal	Normal	Sl discoloration	Dark
Ferripolyphosphate, gel	18.1	52–60[b]	Normal	Normal	Normal	Normal
Ferripolyphosphate, aq soln	1.0	83–93[b]	Normal	Normal	Dark	Dark
Ferripolyphosphate-whey protein	12.5	93–100[b]	Normal	Dark	Dark	Dark

[a] Data of Fritz et al. (1970)
[b] Data of Jones (1972)

Table 2—Discoloration of iron fortified dehydrated mashed potatoes

Iron compound added	Level of addition (mg Fe/100g)	Color of reconstituted product[a,b] Potato flakes 1	2	3	4	Potato granules 5	6
Control	0	N	N	N	N	N	N
Ferric chloride	5	S	D	D	D	D	S
	10	S	D	D	D	D	D
Ferripolyphosphate, gel	5	N	S	N	S	S	N
	10	N	S	D	S	D	N
Ferripolyphosphate, aq soln	5	N	N	N	N	N	N
	10	N	S	N	N	D	N
Ferripolyphosphate-whey protein	5	S	D	D	D	D	D
	10	S	D	D	D	D	D

[a] N = normal color; S = slight discoloration; D = dark.
[b] Commercial products 1–4 (flakes) and 5–6 (granules) were fortified during reconstitution.

from subdivided Idaho Russet Burbank potatoes which had been boiled for 25 min. Coded fortified samples and an unfortified control were examined under fluorescent lighting for color differences immediately and after 30 min (in a boiling water bath) by a panel of at least three judges. Samples were judged subjectively for degree of discoloration in comparison with the control, i.e., normal color, slight discoloration, or dark, and the panel consensus was obtained.

In addition iron compounds were evaluated in a number of commercial dehydrated mashed potato products which represented the commonly used processing methods. Iron compounds were added to mashed potatoes prepared from 15-g portions of each product reconstituted with 85 ml boiling water. Coded fortified products and unfortified controls were examined immediately for color differences by at least three judges as described above.

Effect of iron compounds on the storage stability of potato flakes

Iron fortified potato flakes and unfortified controls were produced from Norchip tubers in the pilot plant of the Red River Valley Potato Research Center (East Grand Forks, Minn.) using a modification of the standard process described previously (Sapers et al., 1973). Iron compounds were added to the mash prior to dehydration at two levels corresponding to 5 and 10 mg Fe per 100g potatoes. On the basis of the initial screening for discoloration, two iron sources were selected for stability testing. These were a ferripolyphosphate solid gel containing 18.1% iron, which was provided by the Milk Properties Laboratory, ERRC, and an aqueous ferripolyphosphate solution containing 1% (w/v) iron, prepared fresh from ferric chloride and Calgon as described by Jones et al. (1972). Flakes were shipped to ERRC, air- and nitrogen-packed in No. 303 and No. 10 cans, and stored at 23° and −18°C for 10 months.

Initial color differences were determined by the same procedure used in the screening studies.

Flavor evaluations were carried out at zero time and after 5 and 10 months storage using a 15-member trained taste panel as described by Sapers et al. (1972). Panelists were asked to rate samples on a five-point scale ranging from five, "same as standard" (control stored at −18°C under N_2), to one, "extreme off-flavor."

Flake samples were analyzed by gas chromatography after 10 months storage for volatile components associated with lipid oxidation; headspace vapor and volatile concentrate procedures described previously were used (Sapers et al., 1972). Quantitative results were expressed as the sums of mean peak area ratios (component peak area/internal standard peak area) for major volatile oxidation products as described by Sapers et al. (1973).

RESULTS & DISCUSSION

Discoloration in iron fortified mashed potatoes

The addition of iron compounds to both fresh and reconstituted dehydrated mashed potatoes usually resulted in the rapid development of a dark gray-green discoloration (Tables 1 and 2). This defect generally was more pronounced at higher levels of addition. The tendency of a compound to produce discoloration appeared to be more closely related to its biological availability (Fritz et al., 1970; Jones, 1972) than to the oxidation state of iron.

The intensity of color formation varied greatly for the same compound tested in different dehydrated mashed potato products. This variation appeared unrelated to the process (flakes vs. granules) or to the geographic origin of the

Table 3—Stability of iron fortified potato flakes after 10 months in air at 23°C

Flake sample	Mean flavor score, Storage time (months) 0	5	10	Sum of major volatile oxidation products[a] Headspace vapor	Volatile concentrate
Control	4.80	4.00	3.33[b]	0.112	4.22
Ferripolyphosphate, aq soln 5 mg/100g	4.19	2.73[b]	3.07[b]	.415	12.60
Ferripolyphosphate, aq soln 10 mg/100g	4.20	3.87[c]	3.07[b]	.314	7.43
Ferripolyphosphate, gel 5 mg/100g	2.69[b]	2.80[b]	2.94[b]	.312	11.59
Ferripolyphosphate, gel 10 mg/100g	4.07	3.53[b]	2.75[b]	.287	7.42

[a] Mean peak area ratios
[b] Significantly different from hidden standard at 0.01 level
[c] Significantly different from hidden standard at 0.05 level

product; differences in raw material composition and in levels of additives, especially sodium acid pyrophosphate, (SAPP), may have been responsible. This compound is used commercially to inhibit after-cooking darkening in processed potatoes. The addition of 0.03–0.06% SAPP to fresh and reconstituted dehydrated mashed potatoes containing aq. ferripolyphosphate (5–10 mg/100g potato) was found to reduce or eliminate the discoloration in the current study. Unfortunately, any benefits accruing from the use of SAPP in fortified flakes probably would be offset by the poor nutritional availability of the sodium iron pyrophosphate which would be formed (relative biological value of 2–23% according to Fritz et al., 1970).

Of the seven iron compounds screened in fresh and dehydrated mashed potatoes, only the ferripolyphosphate solid gel and aqueous solution showed enough promise to justify further experimentation. When these preparations were used to fortify potato flakes at the Red River Valley Potato Research Center, some discoloration was observed after the addition of the ferripolyphosphates to the mash. Subsequent examinations of reconstituted samples indicated that the fortified mashed potatoes were moderately discolored, the discoloration being more intense at the higher level of addition (10 mg Fe/100g). More discoloration was produced by the aqueous ferripolyphosphate than by the gel, as might be predicted from the higher relative biological value of the former complex.

Flavor quality and stability of iron fortified potato flakes

Flavor evaluations conducted at the beginning of the 10-month storage period indicated deficiencies in the flavor quality of all freshly processed iron fortified potato flakes (Table 3). The product fortified with ferripolyphosphate gel (5 mg/100g) received an unusually low flavor score; the flavor of this as well as the other fortified samples was considered to be atypical but not rancid.

During storage, all air-packed samples and controls stored at 23°C developed off-flavors indicative of oxidative rancidity. After 5 months storage, flavor deterioration was greater in flakes fortified with 5 mg Fe/100g than at the higher level, the two iron compounds giving similar results. All fortified samples were inferior to the control. After 10 months storage, flavor scores of flakes fortified at the 10 mg Fe/100g level declined further, approaching scores received by flakes fortified at the lower level. The unfortified control received a slightly higher flavor score.

Gas chromatographic data show that after 10 months storage in air at 23°C, the fortified flakes contained higher levels of major volatile oxidation products than did the unfortified control. Oxidation product levels were highest in flakes containing 5 mg Fe/100g; similar results were obtained with both iron polyphosphate complexes.

The rather surprising response of potato flakes to fortification level may be due to the proportion of iron in the ferrous and ferric states. This proportion would be determined by such factors as the concentrations of ferripolyphosphate complexes, sodium acid pyrophosphate, hydrogen ion and sulfite. The mechanism of catalysis and extent of oxidation might be expected to vary with the oxidation state of iron (Ingold, 1962). Edmondson et al. (1971) reported that whole milk fortified with iron developed an oxidized flavor with ferrous but not ferric compounds.

CONCLUSIONS

FORTIFICATION of dehydrated mashed potatoes with iron at nutritionally significant levels results in after-cooking darkening during processing and reconstitution. The tendency for an iron compound to induce this discoloration is directly related to the relative biological value of the compound.

Iron fortified potato flakes are unstable during processing and storage, developing objectionable off-flavors accompanied by high levels of volatile components associated with oxidative rancidity.

For these reasons, the use of dehydrated mashed potatoes as a vehicle for iron fortification by the procedures reported herein is not considered to be feasible. An alternative approach to iron fortification, for example, microencapsulation, might warrant further consideration. A suitable encapsulating agent would be required to maintain its structure during product preparation and then undergo biodegradation after ingestion.

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